Economic Analysis of Adopting Liberty Link Rice

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Abstract: Although not yet commercially available, the medium grain Liberty Link Bengal currently being developed may be the first biotech rice variety available to U.S. rice farmers. Liberty Link rice technology can assist farmers in controlling red rice, a severe problem in much of the southern rice growing area. Red rice both raises costs to growers and lowers product value. The net benefits of adopting Liberty Link rice are estimated, as well as the potential distribution of benefits of adoption between farmers and seed companies. Yields, production costs, and farm practices are the main factors determining the net benefit—and hence adoption—of Liberty Link technology.

Keywords: Biotechnology, red rice, herbicide-tolerance, yields, adoption rates, technology fees.

Production costs for rice are high compared with most alternative crops. Although not yet commercially available, biotech rice has the potential to both reduce production costs and increase product value. This paper examines the potential farm level effects on profitability of adopting one of the recently developed herbicide-tolerant rice varieties.

A major factor contributing to higher production costs for rice is weed control, especially for red rice, a weed that cannot be controlled easily with conventional herbicides in rice fields. Consequently, much of rice in the southern United States is produced in rotation with soybeans. Even with herbicide applications to kill the red rice in soybeans, red rice survives into the following rice rotation due to the survivability of the red rice seeds over several years.

In an effort to reduce the red rice problem, biotech rice seeds have been developed that resist the wide spectrum herbicide, *Liberty glufosinate*. If successful, this technology would enable U.S. farmers to produce higher valued rice at lower costs. It would also permit farmers more flexibility in crop rotation, enabling continuous rice rotations in response to market returns.

Higher productivity would improve U.S. competitiveness in the global rice market, provided that biotech rice is accepted in the market place. Unlike earlier biotech field crops such as soybeans and corn, Liberty Link rice has not yet been released for commercial production and is not yet approved for use in major export markets.

Several challenges face the release of herbicide-tolerant rice varieties. First, there is the potential for cross-pollination of the genetically modified rice with red rice. Expression of the semi-dwarf characteristic in red rice is a known example of the cross-pollination effect. A second challenge is related to the growing resistance by consumers and food processors to genetically-modified crops and the difficulty of maintaining adequate segregation as the crop moves through market channels.

This paper measures the potential economic benefits to rice farmers of adopting the Liberty Link rice technology. Three important assumptions are made. First, it is assumed that the technology is acceptable to consumers, and therefore, market prices will not differ for conventional and biotech rice with similar end-use characteristics. Second, a farmer's decision to adopt biotech rice is based on the net benefit associated with the technology. And third, the market price and trade effects are assumed to be negligible and are not analyzed in this paper.

If the technology becomes available in a broader set of rice varieties, it would likely lead to lower market prices. The extent of price drop would depend upon the extent of adoption and acceptance in the market place. That analysis is beyond the scope of this paper. The following section describes the problem of red rice in the United States and presents an overview of herbicide-resistant biotech rice varieties. A farm-level analysis of the economics of adopting Liberty Link glufosinate technology follows.

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Red Rice Raises Production Costs And Lowers Product-Value

Red rice is a weed that infests much of the southern rice growing area in the United States. It is a wild rice type that competes with cultivated rice for nutrients, water, and space. Currently, any herbicide that would kill red rice would harm the cultivated rice. While California appears virtually red rice free, all southern rice producing States—Arkansas, Louisiana, Mississippi, Missouri, and Texas—have infestations that have endured since rice was first introduced.

Although red rice is an annual plant, it persists in rice fields because of the long dormancy of its seeds. Once in the soil, red rice seeds may readily germinate or stay latent for a long time before germinating. Red rice exhibits an uneven development period and produces seeds that shatter upon reaching maturity. Because selective weed control between red rice and cultivated rice is difficult, herbicides have not been able to successfully control red rice.

Farmers currently control red rice by depleting the seed bank through an integrated weed management program that combines preplant-incorporated herbicide applications, continuous or pinpoint flooding, and crop rotations. In Arkansas, farmers typically grow soybeans for 2 years and plant rice the third year. This program has severe drawbacks because it seldom completely eradicates red rice. In fact, if just 5 percent of the red rice survive, a seed bank can be restored. In addition, in the last few years returns to soybeans have been, on average, lower than for rice production.

The costs associated with controlling red rice depend on the weed management practices employed. Current systems are expensive and time consuming because several herbicides are required to manage various grasses and none can selectively kill red rice without injuring commercial rice. Controlling red rice also involves flooding and crop rotations. In addition, red rice plants can grow tall and may lodge when mature. This can cause the cultivated rice to lodge as well as increase harvesting and drying costs. Without better weed control, red rice will continue to reduce farm yields and lower grain value.

Red rice also raises milling costs. Red rice produces seeds with either black or straw-colored hulls. When harvested, they mingle with commercial white rice. Removing the red seeds from the commercial rice is necessary but raises costs to the miller, who in turn discount the price to the farmer (see special article box titled—Red Rice Cuts Farmers' Yields and Lowers Price). Red rice removal requires additional milling and separation through a sorting machine. The additional milling decreases the milling yield because of greater breakage and damage to the rice kernel. The higher content of broken grains reduces the value of the milled rice.

Red Rice Cuts Farmers' Yields and Lowers Price

Two approaches have been used to estimate the impact of red rice on farmers' returns. The first approach used yield differences to estimate the impact of red rice on farm productivity. Pantone and Baker (1991) demonstrated the correlation between yield loss and red rice density in Louisiana. They found that it takes up to three cultivated rice plants to offset the yield loss caused by a single red rice weed. Smith (1981) reported that red rice densities of three plants per square meter reduced rice yields 10 percent; 19 plants per square meter reduced rice yields 50 percent. Similarly, Fisher and Ramirez (1993) reported that a 5-percent red rice density per square meter decreased yields 50 percent, and a 20-percent red rice density decreased yields 60 percent.

The second approach analyzed how red rice affects the market value of rice. Brorsen et al. (1984) applied a hedonic pricing model to rough rice markets to analyze the role of quality factors in rice prices. They found that the impact of red rice on the price of rice was twice as high as rice grades alone indicated. Hence, the grading system alone is an inadequate representation of price differences. Using 1981-82 rice data, they found that the presence of red rice decreased the price of rice by 6 cents per hundredweight (cwt) in Texas. Assuming a yield of 60 cwt per acre, this would lower returns $3.60 per acre.

In another study, Brorsen et al. (1988) estimated the effects of quality factors on the value of rice in Texas. Using data from 1982-84, they found that the discount for red rice was relatively stable for all markets and years, ranging from $0.17 to $0.23 per cwt of rough rice. They found the presence of red rice in commercial rice cost farmers $7.38 to $10.41 per acre. This implies that farmers experiencing red rice problems are more likely to adopt biotech rice than farmers not suffering red rice problems. Brorsen et al. also found that when red rice was unchecked it caused harvest quality to decline, resulting in a price discount of 0.9 to 3.2 percent[1].

[1] Using the 1983-84 average price of rough rice ($7.13 per cwt) the price discount is 0.23/$7.13 or 3.2 percent.

Weed Control and Higher Nutrition are Objectives of Rice Biotech Development

Several improved rice varieties are currently being developed that have enhanced qualities for consumers or are herbicide-tolerant. These varieties include Golden Rice, Clearfield IMI (*Imidazolinone*) rice by American Cyanamid, and Liberty Link rice by Aventis.

Golden Rice was developed when two genes from a daffodil and a gene from a bacterium were inserted into the rice germplasm. The combination resulted in a new variety of rice with a higher vitamin A content. A variant of Golden Rice is being developed using three other genes in an effort to provide not only vitamin A, but also an iron supplement. These rice varieties are important because of their enhanced value to consumers.

Clearfield IMI, tolerant to imidaziolinone herbicide, is a conventionally mutated rice variety rather than transgenic. Thus IMI rice is not considered a biotech variety and may not face the challenges of public resistance to genetically modified food. Liberty Link rice contains a gene that triggers an enzyme to confer it special traits to survive nonselective herbicides. Clearfield IMI and Liberty Link are important from the perspective of producers and the environment, because they can reduce the cost and quantity of herbicides used to control red rice. However, whether the overall production costs will be reduced depends on the technology fee and the prices of seeds and herbicides. Some biotech varieties have the potential to produce higher quality rice, resulting in a price premium to the producer.

Liberty Link rice was deregulated by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service in 1999 and may become the first biotech rice on the seed market. Liberty Link rice was developed by the insertion of the bar gene encoding *Phosphinothricin acetyl transferase* (pat) derived from the bacterium *Streptomyces Hygroscopicus*, into Bengal rice, a popular southern medium grain variety. Bengal is an early-maturing medium grain variety developed by Louisiana State University (LSU) and released in 1992. Based on this experience, LSU initiated the development of a biotech variety with a herbicide tolerance. It is expected that early-maturing varieties such as Bengal provide a partial barrier to the hybridization of red rice with pollen flow from cultivated rice.

The pat gene was inserted into the rice tissue to eliminate glutamine synthetase, which causes a fatal accumulation of ammonia in normal plants. The tissues were used to regenerate a transgenic rice variety, which was evaluated in greenhouses and field trials for tolerance to herbicides. The new variety is resistant to glufosinate ammonium, an herbicide that controls several weeds, including red rice.

Glufosinate ammonium controls red rice and other weeds in fields sown to Liberty Link rice. Research by the University of Arkansas at the Rice Research Experiment Station in Stuttgart reported that efficient weed control was achieved with two applications of glufosinate ammonium at 0.375 pounds per acre during the growing season (Wheeler et al.). The first treatment occurred when young rice seedlings had less than three leaves. The second application was made when rice plants reached five or six leaves. In Arkansas, where drill seeding is common, regular rice typically undergoes three herbicide applications by ground or air, plus two post-plant applications of propanil by air.

Budgeting Framework Utilized To Measure Impact of Liberty Link Rice

In order to assess the economics of adoption of Liberty Link rice, a partial budgeting scenario was developed. The scenario was used to construct a baseline and alternative scenario of adoption. The baseline scenario estimates the net benefit from adopting the Liberty glufosinate technology. The net benefit is the difference between the returns per acre of Liberty Bengal and the returns per acre of regular (or non-biotech) Bengal.

The Arkansas Cooperative Extension crop budgets for 2000 were used to measure the net benefit on silt loam and on clay soils under both till and no-till production systems in eastern Arkansas. Three factors are considered in estimating the benefit of Liberty glufosinate technology: costs, yields, and farm price.

Cost Saving:

Liberty Link technology could potentially change input use for seeds, herbicides, labor, and equipment. Direct production costs for conventional rice are estimated at $269.49 per acre on silt loam soils and $289.74 per acre on clay soils. On silt loam, farm expenses include seeds (5.3 percent), herbicide (16.9 percent), labor and custom work (40.3 percent), fungicide and fertilizer (14.4 percent), machinery and custom work (18.2 percent), and interest (3.3 percent). Clay soil farms involve higher costs for seeds, herbicide, irrigation labor, and machinery than silt loam farms. However, they use less fertilizer and custom work.

Liberty Link technology could require fewer applications of glufosinate ammonium (Liberty herbicide) than needed when using a combination of several selective herbicides. If adopted, Liberty Link rice would require two herbicide applications of 0.22 gallon per acre on silt loam and 0.3 gallon per acre on clay soil. No-till rice involves three applications, including one treatment prior to seeding. Liberty herbicide costs $80 per gallon plus a custom fee of $4.50 per application per acre. At harvest, rice is hauled and dried at 42 cents per bushel.

Finally, because the technology has not been released commercially, the technology fee has not been established. In order to identify the range within which the fee is likely to be set, we first evaluate the total rent generated by the technology. To do this we set the technology fee at zero and the price of the Liberty Link seeds equivalent to seeds for conventional Bengal. This is necessary in order to conduct a sensitivity analysis using a reasonable estimate for the technology fee.

Yield Effect:

Under weed-free conditions, Liberty Link Bengal yields 5 to 10 percent less than regular Bengal. However, under moderate to severe weed infestation, conditions in which Liberty Link Bengal would be considered as an alternative variety, yields are 20 percent or more higher, depending upon the degree of red rice and other weed infestation and other cultural conditions and practices (Johnson). Studies on red rice have found that adequate control of red rice improved yields on highly infested plots (Smith; Fisher and Ramirez). With a mild infestation, Liberty Bengal can experience a yield drag similar to the drag observed on biotech soybeans. In 1998, the yield drag on Roundup Ready soybeans was 0 to 10 percent, with a 6-percent average (Benbrook). The baseline scenario assumes the yield of Liberty Link Bengal is equal to the yield of regular Bengal. Thus, both are set at 6,800 pounds (or more than 150 bushels) per acre to represent the average rice yield in eastern Arkansas.

Price Effect:

Rice quality affects the price received by farmers because prices typically include a discount based on the percent of red rice. Liberty Link rice can significantly decrease the number of red rice seeds in rice and improve the quality of the crop. The base scenario assumes a U.S. Grade Number 2 for Liberty Link Bengal and a U.S. Grade Number 3 for regular (or non-biotech) Bengal. The price of medium grain rice is set at $6.50 per cwt. A 30-cent premium per bushel is paid for medium grain U.S. Grade 2 over U.S. Grade 3 in Arkansas. (See special article box—Red Rice Cuts Farmers' Yields and Lowers Price).

Net Benefit of Adoption Higher for Farms With High Red Rice Infestation

In the scenario, the net benefit associated with adopting Liberty Link technology with baseline assumptions was found profitable on all types of soils, with no-till farming generating the highest return. The net benefit per acre was estimated to be $32.62 on clay soils, $31.56 on silt loam, and $40.87 on silt loam under no-till, suggesting that farming practice is an important factor in deciding to adopt

Table E-1--Cost and quality effects are estimated to be top benefits of adopting Liberty Link Bengal 1/

	Non-biotech Bengal			Liberty Link Bengal		
Direct costs	Silt Loam	Silt loam no-till	Clay	Silt Loam	Silt loam no-till	Clay
	$/acre					
Rice seed	14.30	15.73	17.88	14.30	15.73	17.88
Custom work	89.13	98.30	86.83	87.38	87.55	87.38
Fertilizer and lime	32.19	32.19	24.49	32.19	32.19	24.49
Fungicide and seed treatment	9.30	13.52	10.40	9.30	13.52	10.40
Herbicides	45.58	63.34	61.48	35.93	53.89	48.50
Irrigation	1.45	1.45	1.45	1.45	1.45	1.45
Operator labor	10.44	5.83	10.59	10.44	5.83	10.59
Irrigation labor	8.97	8.97	11.96	8.97	8.97	11.96
Diesel fuel	23.51	19.36	28.33	23.51	19.36	28.33
Repair and maintenance	25.63	18.07	26.66	25.63	18.07	26.66
Subtotal	260.50	276.76	280.07	249.10	256.56	267.64
Interest on operating capital	8.99	9.76	9.67	8.72	8.98	9.37
Total direct cost	269.49	286.52	289.74	257.82	265.54	277.01
	$/cwt					
Farm price	6.50	6.50	6.50	6.50	6.50	6.50
	Cwt /acre					
Yield	68.00	68.00	68.00	68.00	68.00	68.00
	$/acre					
Quality discount	-19.89	-19.89	-19.89	0.00	0.00	0.00
Total revenue	422.11	422.11	422.11	442.00	442.00	442.00
Returns on direct costs	152.62	135.59	132.38	184.18	176.46	164.99
Net benefit of Liberty Link Bengal				31.56	40.87	32.62
Cost effect				11.67	20.98	12.73
Quality effect				19.89	19.89	19.89

1/ Cost and revenue data for non-biotech rice from 2000 Arkansas Cooperative Extension Crop Budgets. For Liberty Link Bengal, all cost and revenue estimates developed by authors. Liberty Link Bengal is not yet commercially available.

Liberty Link rice. Assuming a yield of 150 bushels per acre, the scenario indicates that Liberty Link rice could increase returns $0.21 to $0.27 per bushel to be distributed between the rice producer and the technology owner. Since no technology fee was assumed in the base scenario, the net benefit is also a measure of the technology rent.

The net benefit includes a quality effect of $19.89 per acre that results from a price premium of 30 cents per bushel for Liberty Link rice over regular rice. In addition to the price premium, there is a cost saving of $20.98 per acre on no-till silt loam, a $11.67 per acre savings on silt loam, and a $12.73 per acre savings on clay. The cost saving consists of reduced herbicide use and a reduction in custom work. The baseline scenario does not include a yield effect.

Distributional Benefits

The distribution of benefits between the farmer and the technology owner (the seed company) is largely a function of the technology fee. The baseline scenario assumes that the technology is free in order to estimate the total rent creation. This scenario is expanded to estimate the farmer's net gain and the returns to the seed company given various levels of technology fees. It is assumed that Liberty products have no substitutes and the lack of competition is important in the company's pricing decision.

No attempt was made to determine how or if a technology fee will be set for Liberty Link rice seeds and herbicide. Liberty Link rice is a single-gene-technology similar to the Roundup Ready soybeans (RRS) for which farmers pay a technology fee built into the price of seeds. Therefore, RRS is used as a reference for setting a reasonable cost of the Liberty Link technology. The retail price of RRS seeds is $23.95 per 50-pound bag, including an $8.00 technology fee. Assuming a seeding rate of 60 pounds per acre, RRS seeds cost $28.75 per acre, including a technology fee of $9.60 per acre. With a retail price for conventional soybean seeds of $15.00 per 50-pound bag, a farmer planting RRS is required to pay a technology fee 60 percent higher than the cost of regular seeds.

The retail price of regular Bengal seeds in Arkansas is $6.50 per bushel. The seeding rate is 2.2 bushels per acre on silt loam soil and 2.42 bushels under no-till. On clay soil the seeding rate is 2.75 bushels per acre. Hence, seed cost varies from $14.30 to $17.88 per acre. A 60-percent price increase in seed price would put the price of Liberty Link seed at $22.88 to $28.81 per acre, including a technology fee of $9 to $11 per acre. This is within the range of $31 to $40 per acre estimated for the total rent generated by the technology. The impact of a technology fee between $5 and $25 per acre on adoption is measured. In addition, the scenarios assume a yield improvement of 5 percent and 10 percent on farms that experience a serious red rice problem and a yield drag of 5 percent and 10 percent on other farms.

Yield Drag and Higher Seed Costs Reduce Benefits to Liberty Link Rice

The net benefit of Liberty Link rice is dependent on yield, technology fee, and land characteristics. With no yield change following adoption, farmers earn $28.19 per acre on silt loam under no-till when the company sets a technology fee of $10 per acre. The farmer's net benefit decreases to $9.37 per acre when yield drag is 5 percent and drops to -$9.46 with a yield drag of 10 percent. The overall results show that a yield gain (drag) of 5 percent increases (decreases) the profitability of Liberty Link rice $18.83 per acre. In other words, a 1-percent increase (decrease) in yield results in a $3.77-increase (decrease) in the farmer's net benefit.

In this scenario, Liberty Link rice is profitable if the technology fee is below $15 per acre and the yield drag does not exceed 5 percent. With a technology fee of $15 to $25 per acre, the net benefit is still positive if there is no yield drag. Liberty Bengal is unprofitable for any technology fee if the yield drag reaches 10 percent. The results show that the farmer's net benefit is negatively correlated with the cost of the technology. A $5-increase in the technology fee reduces the net profit of Liberty Link rice $5.18 per acre, including 18 cents of savings on interest.

The results demonstrate that the technology fee and yield drag could be the main factors limiting adoption. On average, the lower the yield drag the higher the net benefit to the farmer and the more likely adoption becomes. For any technology fee level, Liberty Link would be more profitable if it improves yields. Liberty Link would not be profitable if the

Table E-2--Technology fee and yield drag reduce estimated net benefits of adopting Liberty Link Bengal 1/

	Yield change after adoption of Liberty Link Bengal 2/				
Technology fee	-10 %	-5 %	No change	+5 %	+10 %
$/acre	Net benefit of adopting Liberty Link Bengal ($/acre)				
5	-4.29	14.54	33.37	52.20	71.02
10	-9.46	9.37	28.19	47.02	65.85
15	-14.64	4.19	23.02	41.85	60.67
20	-19.81	-0.98	17.84	36.67	55.50
25	-24.99	-6.16	12.67	31.50	50.32

1/ Analysis based on budgeting scenario developed by the authors. Liberty Link rice is not yet commercially available.
2/ Silt loam soil, no-till farming.

yield drag is 10 percent or higher. Similarly, the lower the technology fee the higher the net benefit and more likely the adoption of the Liberty Link technology.

Longer Term Impacts Need To Be Included in Analysis

While this paper provides some insight on the potential profitability of Liberty Link technology, caution is necessary in interpreting and generalizing its results. While the analysis indicates direction and magnitude for changes in profitability due to adopting Liberty Link technology, three limitations are apparent.

First, costs and revenues are analyzed only in the first year of Liberty Link release using Arkansas rice budgets. Agricultural regions experiencing the red rice problem are more diverse. The paper did not account for heterogeneity of rice regions, nor does it consider the relationship between crop rotations and adoption. A longer planning horizon and a whole farm approach would better determine how benefits evolve over time and the producer strategy to maximize farm income rather than rice income alone.

The *second* limitation comes from the ex-ante framework of the study and its hypothesis that adoption solely depends on net benefit. A study of net benefits in an ex-post framework will allow testing the validity of this hypothesis and identifying the role of other factors in the adoption decision.

And *finally*, the paper used a partial equilibrium approach to estimate net benefits and hence, ignored potential changes in the demand for seeds and herbicides. In practice, a general equilibrium approach would include the substitution effects between Liberty Link seed and non-biotech seeds, price and substitution effects for other herbicides, and price and trade effects from supply shifts.

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